BACTERIOLOGICAL WATER QUALITY OF KUSHOG LAKE.

BY
ONTARIO. WATER RESOURCES COMMISSION. DIVISION OF LABS.
BACTERIOLOGY BRANCH

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by

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Abstract

During the summer of 1970, two intensive bacteriological surveys of Kushog Lake showed the lake to be acceptable for total body contact recreational use. In general, the bacterial levels were as follows:

	Survey	
Geometric Mean	June 13-17, 1970	August 12-16, 1970
Total Coliform/100 ml	155	319
Fecal Coliform/100 ml	3	6
Fecal Streptococcus/100 ml	2	4

Some natural pollution of Kushog Lake occurred in the area of Pine Springs and Little Girl Bay. The source of the contamination appeared to be Margaret Creek.

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Introduction:

During the summer of 1970, two intensive bacteriological surveys were carried out on Kushog Lake in Haliburton County.

Kushog Lake is about eight miles long and in most areas about one quarter of a mile wide. The lake is located in Stanhope Township of Haliburton County about ten miles south of the Town of Dorset along Highway 35. The Ontario Forest Ranger School is located on Lake St. Nora which is connected to Kushog Lake by a narrow channel in the north end.

Kushog Lake receives water from Lake St. Nora and numerous small creeks, e.g. Margaret Creek, Hindon Creek and Welch Creek, which drain the surrounding countryside. The lake empties via a stream near station number 4 into Boshkung Lake and the Gull River.

Development in Kushog Lake is centred in three main areas: the shores of Little Girl Bay in an area known as Pine Springs, the shores of the lake north and south of Highway 35 crossing at Ox Narrows, and an area on the southern bays of the lake. The remainder of the lake remains undeveloped or with only a few scattered cottages.

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Methods:

During 1970, two five-day intensive bacteriological surveys, June 13 to 17, 1970 (Survey A) and August 12 to 16, 1970 (Survey B) were carried out on Kushog Lake. Twenty-eight surface stations were sampled daily during the survey period. Station number 11 was not sampled for the bacterial section of this survey, only for the chemical section. All bacterial samples were taken in sterile 250 ml autoclavable polycarbonate bottles from a depth of about one metre below the water surface. After taken, the samples were stored on ice and delivered within 3 to 8 hours to a nearby mobile laboratory for analysis. During the June survey, the samples from twenty selected stations were analyzed for the four bacterial parameters: total plate count, total coliform (TC), fecal coliform (FC) and fecal streptococcus (FS). The remainder of samples were analyzed for total coliform and fecal coliform only. During the August survey, the samples from all stations received analyses for the three parameters: total coliform, fecal coliform and fecal streptococcus. All samples were analyzed by the membrane filtration method as set out in Standard Methods (1) except that MacConkey membrane broth was used for fecal coliforms.

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The results from all analyses were organized as replicates representing the station during the survey period. All data was transformed to the natural logarithm (logarithm to the base e) and all further statistical evaluation was carried out on the transformed data. Initially, geometric means (the antilogarithm of the average of the logarithm data) were calculated for each station and each parameter. Then an analysis of variance or F-test (2) was carried out in order to group stations which were not significantly different one from the other.

The analysis of variance was first performed on all the stations for a given parameter and survey. If some of the stations proved to be significantly different, the data from these stations was removed to a separate grouping. The analysis of variance was then redone until no stations in the group were significantly different. All groups formed by the extraction of stations from the original group were similarly analyzed. A single geometric mean was then calculated for each homogeneous group of stations.

In order to test for significant changes with time, a Student's t test was performed between analysis of variance groupings in the June survey and groupings in the August survey which have stations in common. As with the analysis of

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variance F statistics, the calculated t statistics were compared with the critical values for the suitable number of degrees of freedom presented in standard statistic tables (3).

Throughout the statistical evaluation of the data, all geometric mean bacterial levels were compared with the water quality criteria for total body contact recreational use as presented by the OWRC (4).

Results and Discussion:

The results of the total plate count analyses are not reported in this paper but have been discussed in another paper (5).

The summaries of the analysis of variance grouping of stations are presented in Tables I, III and V. Summaries of the tests of significance (t test) between groups are presented in Tables II, IV and VI. The maps in Figures 1 and 2 show the locations of the stations and the geographical relationship of the analysis of variance groupings.

During the June survey, all stations on the lake showed homogeneous TC levels (overall geometric mean of 155 TC/100 ml) with the exception of stations 9 and 16 which were significantly higher at 461 and 604 TC/100 ml respectively.

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Similarly for FC, only the group of stations 25, 26 and 27 in the Pine Springs area were significantly higher at 20 FC/100 ml than the remainder of the stations which gave an overall geometric mean level of 3 FC/100 ml. FS levels present a similar pattern with station 1 at 25 FS/100 ml while the rest of the lake had a FS level of 2/100 ml.

During the August survey, the pattern of significant station groupings had changed with the stations divided into four groupings on the basis of the TC level. Stations 3, 5, 6, 7, 8, 9, 10, 12, 13, 16, 17, 19, 21, 24, 25, 27 and 28 formed a grouping which had higher TC levels (319 TC/100 ml) in August than in June except for station 9 where the TC level remained unchanged and station 16 where the TC level had decreased. The group of stations 1, 2 and 4 in the southern bays of the lake showed a higher TC level (564/100 ml) than in the June survey. Stations 14, 15, 18, 20, 22, 23 and 29 formed the third grouping on the basis of the TC level. This grouping had a TC level (167/100 ml) which was unchanged from the June survey.

Station 26 at Pine Springs had TC and FC levels (557 and 31/100 ml respectively) which were significantly higher than any of the other stations during the August survey. But the FC level was not significantly different from that for the June survey.

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Except for stations 4, 19, 25 and 28, the FS levels at all other stations were not significantly different (overall geometric mean of 4 FS/100 ml).

All bacterial levels during both the June and August surveys indicated that Kushog Lake was acceptable for total body contact recreational use since at no station or grouping of stations was the water quality criteria exceeded.

However, the analysis of variance groupings did give a picture of sources of pollution in Kushog Lake. During both surveys, the stations at or near Pine Springs (station 25, 26 and 27) had one or more bacterial parameters higher than most of the rest of the lake but never exceeding the water quality criteria. There are two possible sources of this contamination 1) a low level pollution on the part of the cottages in Pine Springs or 2) a natural pollution from the swamps and forest along the Margaret Creek which empties into the lake at this point. The dark chocolate colour of the water in Little Girl Bay would tend to indicate the latter source.

The fact that seven stations remained unchanged in all three bacterial parameters from the June survey to the August survey and that the remaining stations changed only by factors of two or three indicated that pollution sources, if they exist on Kushog Lake, were small.

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In general, then, Kushog Lake was acceptable for recreational use and showed few pollution sources bacteriologically.

References:

1) "Standard Methods for the Examination of Water and Wastewater", twelfth edition 1965, APHA, AWWA, WPCF.

2) Sokal, R.R. and Rohlf, F.J., 1969. Biometry. The principles and practice of statistics in biological research. W.H. Freeman and Company, San Francisco, 776 pp.

3) Rohlf, F.J. and Sokal, R.R., 1969. Statistical Tables, W.H. Freeman and Company, San Francisco, 252 pp.

4) Ontario Water Resources Commission, June 1970. Guidelines and Criteria for Water Quality Management in Ontario.

5) Jones, M., 1971. A Study of the Taxonomic Composition of Bacterial Populations in Fresh Water Lakes. Ontario Water Resources Commission, Division of Laboratories.

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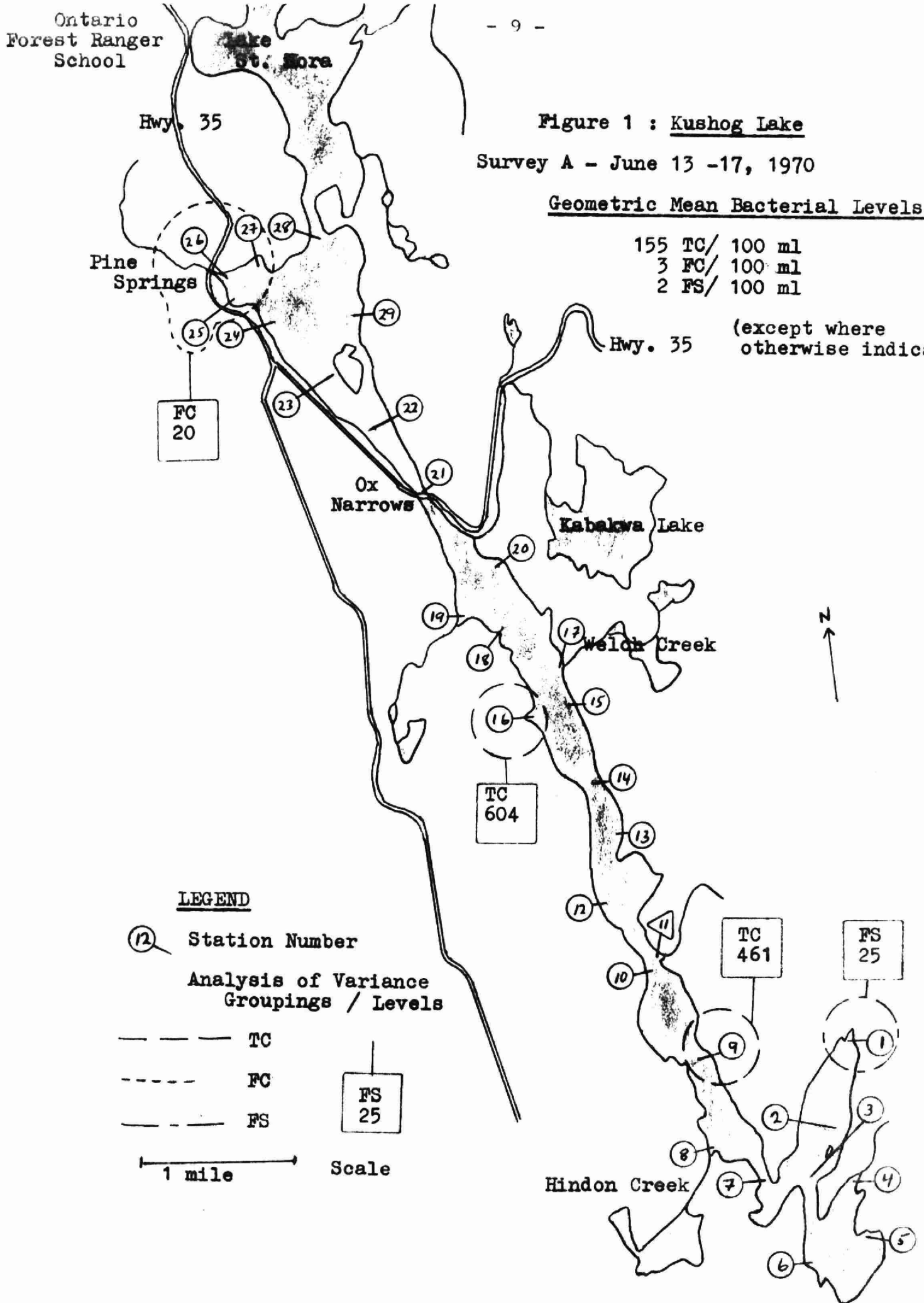

Figure 1 : Kushog Lake

Survey A - June 13 -17, 1970

Geometric Mean Bacterial Levels

155 TC/ 100 ml
3 FC/ 100 ml
2 FS/ 100 ml

(except where otherwise indicated)

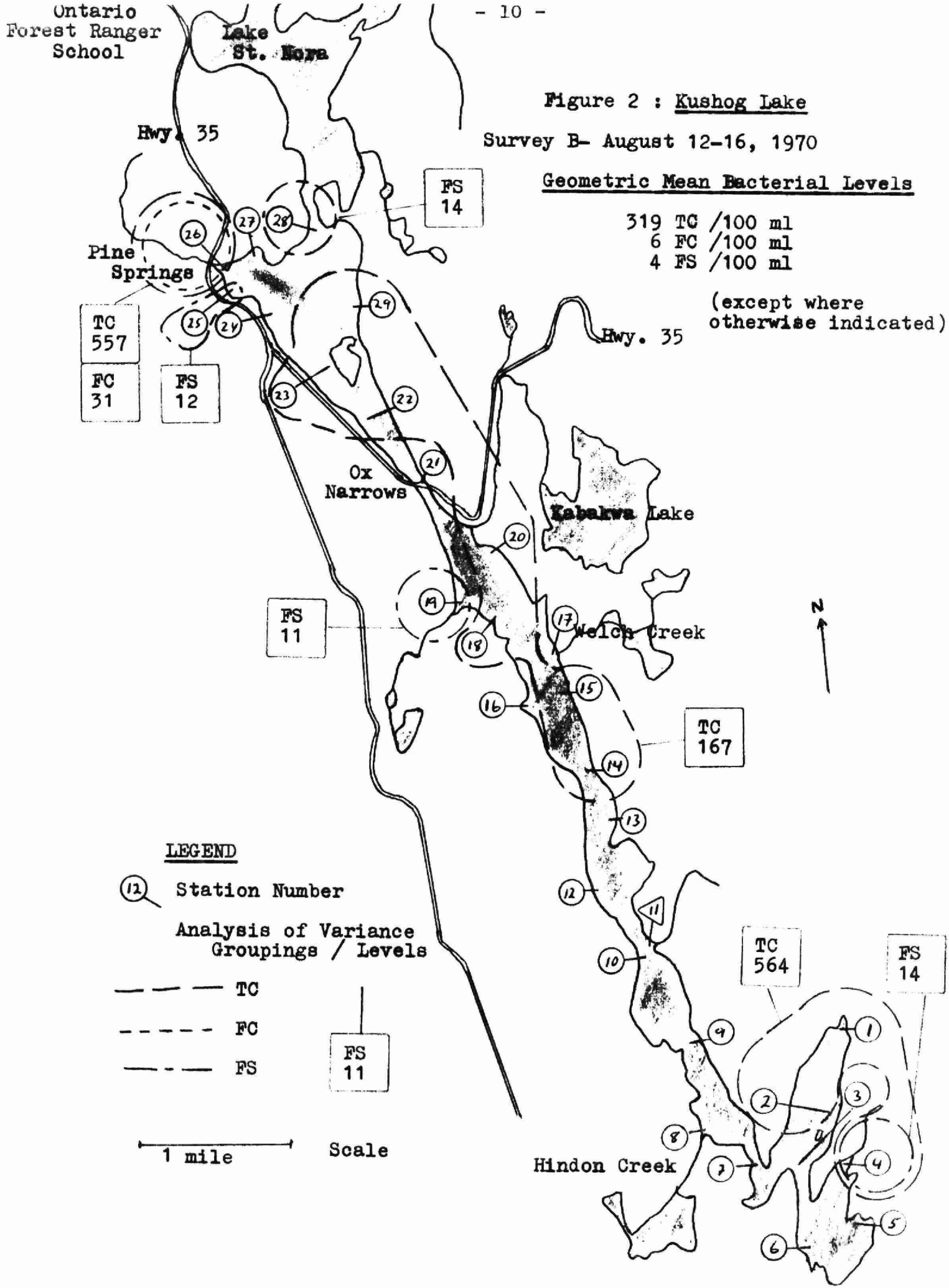

Figure 2 : Kushog Lake

Survey B- August 12-16, 1970

Geometric Mean Bacterial Levels

319 TC /100 ml
6 FC /100 ml
4 FS /100 ml

(except where otherwise indicated)

TABLE I

Summary of the Analysis of Variance Grouping of Stations, Kushog Lake, 1970.

Parameter:	Total Coliform (TC)/100 ml	
Survey:	A) June 13 - 17, 1970	B) August 12 - 16, 1970
Group:	All stations	All stations
F	1.78 df 27, 112	4.33 df 27, 112
F(5%)	1.55	1.55
	SD	SD
Group:	1) All stations except 9, 16	1) All stations except below
F	1.37 df 25, 104	1.52 df 16, 68
F(5%)	1.61	1.84
	NSD	NSD
ln GM	5.0437	5.7663
s^2	1.1124	0.2492
N	130.	85.
GM	155.0	319.4
Group:	2) Station 9	2) Stations 1, 2, 4
F	-	0.40 df 2, 11
F(5%)	-	
	-	NSD
ln GM	6.1331	6.3348
s^2	1.6293	0.3115
N	5.	14.
GM	460.9	563.8

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TABLE I - continued

Parameter:	Total Coliform (TC)/100 ml	
Survey:	A) June 13 - 17, 1970	B) August 12 - 16, 1970
Group:	3) Station 16	3) Stations 14, 15, 18, 20, 22, 23, 29
F	-	1.23 df 6, 28
F(5%)	-	2.45
	-	NSD
ln GM	6.4036	5.1166
s^2	0.3961	0.2098
N	5.	35.
GM	604.0	166.8
Group:		4) Station 26
ln GM		6.3219
s^2		0.7707
N		5.
GM		556.6

NSD = No Significant Difference

SD = Significant Difference at the 0.05 Level.

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TABLE II

Summary of Tests of Significance between Analysis of Variance Groups.

PARAMETER: TOTAL COLIFORM (TC)/100 ml

		Survey A		
	Group	1	2	3
Survey B	1	7.58 SD** df 213	1.43 NSD df 88	2.74 SD* df 88
	2	4.50 SD** df 142	-	-
	3	0.40 NSD df 163	-	-
	4	2.67 SD* df 133	-	-

NSD = No Significant Difference

SD = Significant Difference at the .05 Level

SD* = Significant Difference at the .01 Level

SD** = Significant Difference at the .001 Level

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TABLE III

Summary of the Analysis of Variance Grouping of Stations, Kushog Lake, 1970.

PARAMETER: FECAL COLIFORM (FC)/100 ml

Survey:	A) June 13 - 17, 1970	B) August 12 - 16, 1970
Group:	All stations	All stations
F	3.02 df 27, 112	1.57 df 27, 112
F(5%)	1.55	1.55
	SD	SD
Group:	1) All stations exdept 25, 26, 27	1) All stations except 26
F	1.48 df 24, 100	1.29 df 26, 109
F(5%)	1.61	1.61
	NSD	NSD
ln GM	0.9775	1.7773
s^2	1.0823	1.1329
N	125.	136.
GM	2.7	5.9
Group:	2) Stations 25, 26, 27	2) Station 26
F	0.96 df 2,12	-
F(5%)	3.89	-
	NSD	-
ln GM	2.9690	3.4236
s^2	1.5452	1.5880
N	15.	4.
GM	19.5	30.7

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TABLE IV

Summary of Tests of Significance between Analysis of Variance Groups.

PARAMETER: FECAL COLIFORM (FC)/100 ml

		Survey A	
	Group	1	2
Survey B	1	6.13 SD** df 259	4.05 SD** df 149
	2	-	0.65 NSD df 17

NSD = No Significant Difference

SD**= Significant Difference at the .001 Level

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TABLE V

Summary of the Analysis of Variance Grouping of Stations, Kushog Lake, 1970.

PARAMETER: FECAL STREPTOCOCCUS (FS)/100 ml

Survey:	A) June 13 - 17, 1970	B) August 12 - 16, 1970
Group:	All stations	All stations
F	3.35 df 19, 80	2.10 df 27, 112
F(5%)	1.75	1.55
	SD	SD
Group:	1) All stations except 1	1) All stations except 4, 19, 25, 28
F	1.57 df 18, 76	1.50 df 23, 96
F(5%)	1.75	1.70
	NSD	NSD
ln GM	0.7564	1.3550
s^2	0.7937	1.0200
N	95.	120.
GM	2.1	3.9
Group:	2) Station 1	2) Station 4
ln GM	3.3264	2.6190
s^2	2.5924	3.6151
N	5.	5.
GM	25.4	13.7
Group:		3) Station 19
ln GM	-	2.4111
s^2	-	0.4828
N	-	5.
GM	-	11.1

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TABLE V - continued

Parameter:	Fecal Streptococcus (FS)/100 ml	
Survey:	A) June 13 - 17, 1970	B) August 12 - 16, 1970
Group:		4) Station 25
$\ln$ GM	-	2.4922
s^2	-	1.8098
N	-	5.
GM	-	12.1
Group:		5) Station 28
$\ln$ GM	-	2.6272
s^2	-	0.8129
N	-	5.
GM	-	13.5

NSD = No Significant Difference

SD = Significant Difference at the 0.05 Level

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TABLE VI

Summary of Tests of Significance between Analysis of Variance Groups.

PARAMETER: FECAL STREPTOCOCCUS (FS)/100 ml

		Survey A	
	Group	1	2
	1	4.54 SD**	4.17 SD**
		df 213	df 213
	2	4.26 SD**	-
Survey B		df 98	
	3	4.08 SD**	-
		df 98	
	4	4.14 SD**	-
		df 98	
	5	4.57 SD**	-
		DF 98	

SD** = Significant Difference at the 0.001 Level

APPENDIX A - Explanation of Terms in Tables

F — the calculated analysis of variance statistic or the F ratio.

df — degrees of freedom of the F ratio for "between group" variation and "within group" variation.

F(5%) — the critical F ratio from a statistics table.

If the calculated F is greater than the F(5%), a significant difference (SD) occurs between the groups in the analysis. If F is less than F(5%), no significant difference (NSD) occurs.

ln GM — the natural logarithm of geometric mean for all groups in the analysis of variance when NSD occurs.

s^2 — the variance in natural logarithm.

N — the number of values in the analysis.

GM — the geometric mean of the bacterial level.

t — the calculated test of significance or t-test to determine the between survey difference.

If t for the number of degrees of freedom shown is greater than the critical t value, a significant difference (SD) occurs.